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High $p_\perp$ Spectra from Au+Au Collisions at $\sqrt{s_{NN}} = 130$ GeV

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We report on hadron production at high transverse momentum from Au+Au collisions at $\sqrt{s_{NN}}$= 130 GeV, measured with the STAR detector at the Relativistic Heavy Ion Collider (RHIC). Preliminary negative hadron spectra up to $p_\perp = 6$ GeV/c have been measured, and indicate a suppression at high $p_\perp$ relative to a reference from $p+\bar{p}$ collisions. Preliminary azimuthal anisotropies have been measured up to $p_\perp$=4.5 GeV/c, which are described well by a hydrodynamical calculation below 1.5 GeV/c, but show a significant deviation at higher $p_\perp$. A preliminary ratio $\bar{p}/p$ has been measured by the STAR-RICH detector in the range $p_\perp$=2-2.5 GeV/c.

1. Introduction

Hard processes provide a useful probe for the study of conditions created in heavy-ion collisions at RHIC. In particular, within the framework of perturbative QCD, high $p_\perp$ partons may be expected to suffer a loss of energy as they traverse the dense medium created in the collision zone. Predictions of observable consequences of this energy loss have been made [1,2]. We present here preliminary results addressing these predictions.

2. Experiment and Analysis

The STAR Time Projection Chamber (TPC) [3] measures charged particles over the full azimuth. The TPC is installed inside a solenoidal magnetic field, which for the first RHIC run was operated at 0.25 T. Transverse momentum resolution for charged tracks, as determined from embedding simulated tracks into real events, ranged from $dp_\perp/p_\perp = 2\%$ for pions at $p_\perp = 500$ MeV/c to 15% at 6 GeV/c. An array of scintillator slats surrounding the TPC was used for online triggering on central events. In the extreme forward region, two hadronic calorimeters (ZDC's) provided a minimum bias trigger. Offline selection of the 5% most central events was performed solely using the ZDC's. A Ring Imaging Cherenkov Detector (STAR-RICH) [4], covering $\Delta\phi = 20^\circ$ and $|\eta| < 0.3$ for collisions at the center of the magnet, was installed between the TPC and the magnet in order to extend particle identification capabilities to high $p_\perp$.

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Tracks from charged particles in the TPC selected for this analysis satisfied strict requirements on track quality, as determined by the number of measured points and the distance of closest approach (DCA) to the primary event vertex. Tracking efficiencies including these requirements were obtained by embedding simulated tracks into real events, yielding corrections from 20-35%, depending on track $p_\perp$ and η. Detailed agreement was found between simulated and real tracks. Further corrections due to momentum resolution were found to be negligible below $p_\perp$ = 3 GeV/c, rising to 40% at 6 GeV/c. Background contributions, principally due to the products of weak decays, were assessed using distributions of the DCA of apparent high $p_\perp$ tracks to the primary event vertex in both real events and simulations, yielding corrections from 7-15%.

3. Negative Charged Particle Yields

Figure 1 shows the transverse momentum distribution of negatively charged hadrons (h^-) for the 5% most central Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV. The $p_\perp$ distribution of $(h^- + h^+)/2$ from $p + \bar{p}$ collisions at $\sqrt{s}$ = 200 GeV from UA1 [5] is also shown. The invariant cross-section from UA1 has been scaled by $2\pi/\sigma_{inel}$, with σ_{inel}= 42 mb [6], in order to obtain $1/p_\perp dN/dp_\perp$.

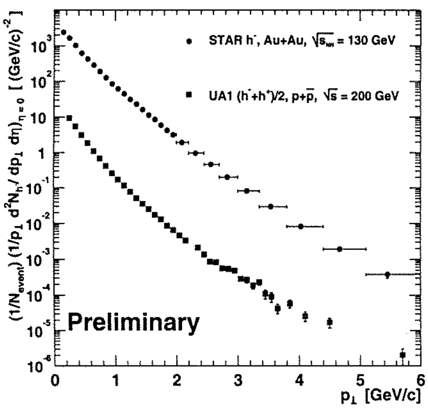

Figure 1. h^- $p_\perp$ spectrum from the 5% most central Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV. Horizontal error bars denote bin widths. UA1 $(h^- + h^+)/2\, p_\perp$ spectrum from $p + \bar{p}$ collisions at $\sqrt{s}$=200 GeV [5].

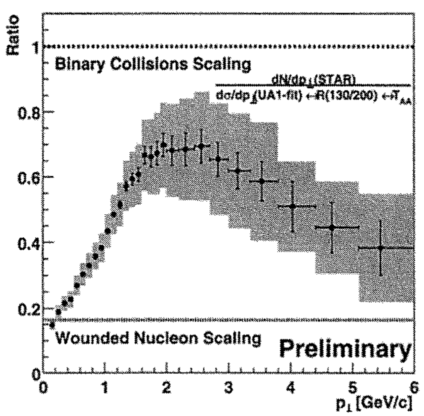

Figure 2. Ratio of STAR and scaled UA1 $p_\perp$ spectra. Vertical error bars denote error on measurement, gray boxes cumulative error including error on UA1 scaling.

Figure 2 shows the ratio of the STAR spectrum to a smooth parametrization of the UA1 spectrum. The denominator of the ratio has been scaled by two factors. First, parameters from fits of UA1 spectra from $\sqrt{s}$=200-900 GeV to the form $Ed^3\sigma/d^3p = A(1+p_\perp/p_0)^{-n}$ [5] were extrapolated to $\sqrt{s}$ = 130 GeV, constrained by scaling laws for $\langle p_\perp \rangle$ and $dN_{ch}/d\eta$ as a function of $\sqrt{s}$ [7], with errors constrained by results from a perturbative calculation [8]. R(130/200), the ratio of the parametrization found at $\sqrt{s}$ = 130 GeV and that at 200 GeV, ranges from 0.92 at $p_\perp$ = 2 GeV/c to 0.45 at 6 GeV/c. Second, the resulting parametrization for $d\sigma/dp_\perp$ has been multiplied by $T_{AA} = 26$ mb^{-1}, the appropriate nuclear overlap integral [9], to account for effects of nuclear geometry in the convolution of binary nucleon-nucleon collision.

Two limits are shown in figure 2. At low $p_\perp$, the data are well reproduced by a scaling with the number of wounded nucleons in the collision. See Ref. [10] for further details. Hadron yields at high $p_\perp$ are expected to scale as the number of binary collisions in the absence of possible nuclear effects, such as isospin, shadowing, initial state multiple scattering [11], radial flow, and partonic energy loss [1]. Such scaling would produce a ratio of unity on this figure. The STAR data show a suppression at all measured $p_\perp$ relative to this expectation.

4. Azimuthal Anisotropy

A complementary method for investigating high $p_\perp$ phenomena uses the analysis of azimuthal anisotropies. An event plane containing the beam axis is constructed using the primarily low $p_\perp$ particles in an event, against which the distribution of particle angles for a given $p_\perp$ is created. The distribution is then Fourier-decomposed to obtain the second Fourier coefficient, v_2, as a function of $p_\perp$. For further details see Ref. [12,13].

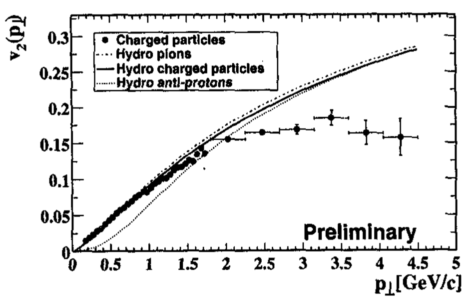

Figure 3. $v_2\,(p_\perp)$, as compared to hydrodynamical calculations [14]. Errors statistical only.

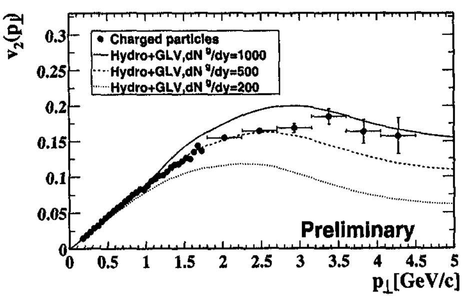

Figure 4. $v_2\,(p_\perp)$, as compared to perturbative QCD calculations [2]. Errors statistical only.

Figures 3 and 4 show $v_2\,(p_\perp)$ from minimum bias events. Errors shown are statistical only, with systematic errors estimated to range from 13% at $p_\perp$ = 2 GeV/c to 20% at $p_\perp$ = 4.5 GeV/c. The hydrodynamical calculation shown in figure 3 describes the data well up to $p_\perp$ = 1.5 GeV/c, above which there is a deviation. Shown in figure 4 is a calculation which combines a hydrodynamical model at low $p_\perp$ with a perturbative calculation incorporating partonic energy loss at high $p_\perp$. Further measurements at higher $p_\perp$ should help elucidate the qualitative agreement seen.

5. $\bar{p}/p$ from the STAR-RICH

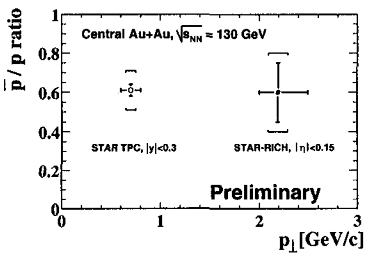

Figure 5: $\bar{p}/p$ at two $p_\perp$ values.

The study of the flavor dependence of high $p_\perp$ particle production may be sensitive to differences between quarks and gluons in propagation through matter[1]. The STAR-RICH [4] identifies charged hadrons at up to $p_\perp = 3$ GeV/c for kaons and 5 GeV/c for protons and antiprotons. Figure 5 shows the ratio $\bar{p}/p$ measured in the STAR-RICH, along with that measured in the STAR TPC alone. This measurement is limited by low statistics from the first RHIC run. Much higher statistics will be available from the second RHIC run, enabling detailed investigations to higher $p_\perp$.

6. Conclusions

High $p_\perp$ hadron distributions may be sensitive probes of the dynamics of nuclear collisions at RHIC, reflecting the interaction of high energy partons with the surrounding medium. The inclusive negative hadron spectrum indicates a suppression of hadron production at high $p_\perp$ in central Au+Au collisions relative to a reference spectrum from $p+\bar{p}$ collisions. The azimuthal anisotropy of hadrons agrees with a hydrodynamical calculation at low $p_\perp$, but is suppressed relative to the calculation above $p_\perp \simeq 1.5$ GeV/c. The $\bar{p}/p$ ratio has been measured up to a $p_\perp$ of 2.5 GeV/c in central Au+Au collisions. The coming high-statistics RHIC run will enable measurements of higher precision at higher $p_\perp$, addressing the question of partonic energy loss in dense matter in detail.

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